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REPORT

OF THE

SUPERINTENDENT

OF THE

GOVERNMENT OBSERVATORY,

COLABA.

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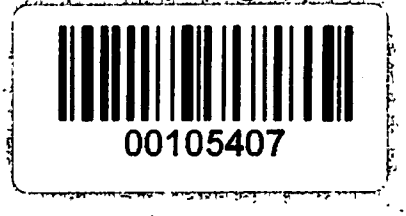
1866.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Letter on the recent Operations and on the necessity for supervision of the Colaba Observatory by the Superintendent.

No. 32 of 1866.

From

The Superintendent, Government Observatory;

To

Colonel Marriott,
Secretary to Government,
Bombay.

Sir,

I have the honor to submit, for the consideration of Government, the accompanying Report on the Instrumental and other requirements of the Government Observatory, for increasing its efficiency and for extending the field of its operations.

I have deemed it necessary, in view of the possibility of the whole scheme being referred, in some stage of its consideration, for the opinion of an experienced magnetician and meteorologist or of some learned body, to treat many points in considerable detail, but in order to facilitate the ordinary reading of the Report, the subjects of the several paragraphs have been marginally indicated.

Having received a copy of the Resolution of Government, Marine Department No. 156 dated the 12th instant, I beg to be allowed to make the following remarks upon paras. 1, 3 and 4, in the hope that they may supply the means of removing an appparent misapprehension of the Government of India, as to the scope for

useful and worthy employment of the Superintendent of the Observatory, pending the provision of improved instruments, &c.

The delay which has occurred in the submission of the scheme of improvements has been caused by circumstances, explained in the Report, over which I had no control, but although the references regarding it and the planning, consideration, and preparation of it have occupied much time, it will be seen (if I note some of the objects of my attention and labour while waiting for the Battery practices and since,) that there has been no waste of time.

In addition to the continuance of the extended regular work of the Observatory, including the registration and reduction of hourly observations, and the reduction of observations made at four permanent minor Observatories in the Presidency, the following undertakings may be mentioned:—

(1.) The axis and bearings of the Large Transit Instrument have been carefully cleaned as well as the level pivots which had become coated with rust; a defective screw removed from the wire plate and the plate fixed firmly. Instrument adjusted, and limits of possible errors due to instrumental imperfections determined; figure of axis found to deviate very sensibly from that of a true cylinder. Readjusted collimator mark which was found in a very unstable condition.

(2) An instrument in store, called a current measurer, altered and fixed upon electrometer tower, for use as an anemometer, until the new intrument arrives.

(3.) There being two thermometers in store whose errors had been determined at Kew, all the thermometers in use at the Observatory have been tested by comparison with these, and their errors, at different parts of the scales, determined; the freezing points have been also independently tested with melting ice.

(4.) All the thermometers regularly observed have been mounted in a wooden cage with open work sides, constructed for exposing the instruments freely to the air while protecting them from radiation and breaking any considerable motion of the air.

(5.) The Vertical Magnetic force records being very unsatisfactory, the box was opened, the knife-edge of the magnet, which had become spotted with rust, was cleaned and the instrument re-adjusted;—box closed up again with dessicating material inside and the joints coated with size to render them approximately air-tight. Before disturbing and after new adjustment of the instrument, the scale-coefficient was determined by means of an apparatus improvised, for the occasion, for Vertical and Horizontal deflection experiments.

(6.) Cleaned and put in order an old horizontal intensity apparatus to serve as a temporary expedient for procuring approximate observations of absolute Declination, and commenced a series of bi-weekly determinations.

(7.) Cleaned Barrow's dip Circle, left in charge by Dr. Livingstone, inserted new spider lines in microscopes, and had needles repaired for temporary use.

(8.) An ineffectual endeavour was made to obtain a special practice with the Colaba Battery, in order to determine the necessity or otherwise for removal of the Observatory. When the regular practices took place careful observations were made, on the several practice days, of every instrument that was liable to be affected by the firing.

(9.) Submitted for the consideration of Government the desirableness of procuring from England a provisional supply of certain new instruments urgently required to remove the more glaring defects in the present instrumental equipment of the Observatory.

(10.) The Harbour and Pilotage Board having expressed their intention of applying to Government for the removal of the Time-Ball to the Fort, the different proposed sites were visited, and the one most suited selected for the purpose; drew up a plan for the requisite alterations of the apparatus and for the construction of a tower for supporting the ball and protecting the apparatus; also, pending the question of the removal of the Observatory, for an auxiliary system of star observations to be made on the spot, and further for ultimately connecting the machinery with the Observatory clock by telegraph; arranged method of working the scheme and the special establishment required for it. Cleaned and tested small Transit instrument proposed to be used for this purpose by adjusting it on a firm temporary support prepared for the occasion and making simultaneous observations, on successive nights with it and the large Transit instrument.

(11.) Reorganized the system of hourly observations, so as to allow a definite portion of each day to be employed by the observers in computations, or in receiving instruction in, and practising, the experimental observations for absolute determination of magnetic elements.

(12.) Put in hand the reductions of the whole body of observations (since the commencement of the Observatory) of Magnetic Declination, for the separation of disturbance observations, and the subsequent exhibition of their laws and the purification of those of ordinary variations;—also the computations for finding the temperature corrections of the Horizontal Force and Vertical Force Magnetometers.

The reduction of seven years' Declination disturbances has already been effected, and so satisfactory are the results derived from the observations made during this comparatively short term, that if extended over the whole period of the Bombay observations

and placed before the world, I may confidently engage that the estimation in which this Observatory is held by men of science will be very materially improved, and thus secure some return for the liberality displayed in the maintenance of the establishment for so long a period. It is easy to see that when a period of ten years is in question, the value that would be attached to conclusions drawn from upwards of twenty years' observations will be very great, even if only in confirmation of those derived from shorter periods of observation; and no series yet fully decennial has extended nearly over a complete cycle of the decimnal period. The seven years' results are the more valuable also since they prove the fidelity with which the phenomena have been recorded throughout the whole period over which the observations extend. I do earnestly hope therefore, that, on reconsidering the matter with the information called for in the Resolution, the Government of India will be induced not to insist upon a limitation of my temporary appointment, which would interfere with the completion of this task.

Further the Home Government having sanctioned the supply of the new instruments alluded to above, it is to be feared that some of the benefits to be expected from their use will be lost if there should be no competent person at hand to instruct the observers in the manipulation and uses of the different parts of the apparatus; it is likely too that, with the exception of two or three officers in the Survey Department, no persons in India, much less in Bombay, have had experience in the use of these instruments which are of comparatively modern design. A portion of them will also require some judgment and experience in selecting the best places for, and in fixing them so as to secure the most efficient action. Respecting two of the most urgently needed instruments, I have been informed from England that they may be expected here in the course of a few weeks.

I may be pardoned also for pointing out that although it is not to be expected that Government would sanction the

permanent appointment of a Superintendent of the Observatory, unless willing also to furnish him with the best means of rendering his labours effective and valuable, yet it is without reference to any very costly instrumental improvements (and the removal of the Observatory does not appear to be insisted on as an essential or immediate requirement) that the Committee of Enquiry in their report, so persistently and so strongly urge upon the notice of Government the need of continuous and effectual supervision in the production of the Observatory records and of intelligence and experience in making use of them when obtained; this will appear from the following extracts from the Committee's Report.

Para. 11. "As the safety of many lives, as well as of so much wealth, depends to such an extent on the correctness of the indications of these instruments, the Committee are of opinion that the maintenance of correct time, dropping the time-ball, and rating chronometers, should be under the constant and direct superintendence of a skilled European."

30. "Meteorological observations * * * * require not only perseverance but considerable scientific intelligence, and the Committee think the observations should be made under the immediate supervision of a European of scientific education."

35. "Both in Meteorology and Magnetism, the condition of the instruments requires constant attention and perpetual revision under skilful superintendence in order to preserve them absolutely as well as relatively correct. Verification there seems to have been none, nor could any one be trusted to verify even a thermometer, which requires some special scientific knowledge."

37. "This exercise of independent intelligence, the Com-

mittee need scarcely add, can only be fairly expected from a Superintendent who can devote the whole of his time and attention to the work of the Observatory."

42. "No amount of observations amassed on the present system, without constant scientific supervision and with instruments the accuracy of whose indications is unknown, will ever be of any value. What is now most urgently required is careful scientific discussion" (of the observations).

50. "The necessity of giving the exact time to the valuable shipping in so great a commercial port is of itself an object of so much material importance, as to render the Astronomical department of the Observatory indispensibly necessary, and this alone would require the services, and ought to be under the direct and constant superintendence of a European well qualified for the duties of his office and who would require a native assistant; and if competent for the conduct of the other departments also and enabled to devote the whole of his attention to the work of the Observatory, a slight addition of observers and computers on very moderate salaries would enable him to continue the operations of the Observatory in Meteorology and Magnetism."

Moreover, if it be remembered that the British Government has continuously maintained, since about 1841, an establishment for the reduction and discussion of the observations made at the Colonial Observatories, and that from this source have proceeded nearly the whole of the large contributions that have been made in the last quarter of a century to Magnetical knowledge, it will be evident that there is much to be done before the accumulation of 20 years of crude observations made at Bombay can be made to yield the fruit which there is every reason to believe they are

calculated to afford, but which must remain of no value for scientific purposes, though they have been produced at a large cost, until this be accomplished.

I have, &c.,

C. CHAMBERS,
Supt., Government Observatory.

Government Observatory,
Colaba 27th March 1866.

Report on the Instrumental and other requirements of the Government Observatory, Colaba, for increasing its efficiency and extending the field of its operations.

Part I.

Authority for presenting this Report; and subjects discussed.

As an immediate object of my appointment as Superintendent of the Observatory I am required, by the Resolution of Government, Marine Department, No. 487 dated 10th August 1865, to prepare a complete scheme, first of instrumental improvements requisite for the efficient working of this Establishment, and secondly for the provision of a more convenient Observatory. Of these the latter naturally claims the first consideration.

*1st.—On the necessity for a new Observatory.**

Vicinity of battery, the principal objection to present situation of Observatory.

2. The principal objection raised against the present site of the Observatory, is that the firing of a battery of heavy Armstrong guns in the adjacent compound must prove injurious to the magnetometers. If the supporting pillars of the magnetometers were thereby permanently and sensibly disturbed and the means of connecting the observations made before the gun practice with those obtained after it, thus destroyed, this objection would be insuperable; but this is rather a question to be decided experimentally than one upon which *an priori* judgment can be

By reason of disturbance of magnetometer pillars.

Weight of objection to be determined experimentally.

* In going back a step and first enquiring more fully than has been done before into the necessity, as seen from a professional point of view, for a new location of the Observatory, I trust that, in view of the serious importance of the subject and the weight of the reasons advanced for believing the expense that would be involved to be uncalled for, I shall not be deemed to have exceeded my province.

safely formed, and feeling that (as means of testing it would be available without any serious delay,) the opinion expressed in the Report of the Committee of Enquiry on this subject, should be confirmed by actual experiments before recommending to Government so serious an expediture as the erection of a new Observatory would involve, I have deferred the submission of the present Report until a practice with the guns should furnish information upon which a decided opinion might be formed.* Besides, as many of the arrangements for the accommodation of new instruments must be fixed with relation to the building they are to occupy, it has been unavoidable that the question of the removal of the Observatory should be decided, before the planning of other arrangements could be particularly entered upon.

Cause of delay in submission of Report.

3. On the 9th, 10th, 11th, 12th, and 17th of January 1866 the following observations of the magnetometers were made simultaneously with the firing of the guns, with the object of determining this question; from them it will be seen that no disturbance of the instruments occurred which might not be attributed to other causes (which can be controlled) with greater probability than to the movement of the pillars upon which the instruments are mounted, and that very frequently no disturbance was perceptible although the means of detecting it, if occurring, were of the most delicate description.

Observations were made simultaneously with firing of battery.

Results of these observations.

4. *Observations made to determine the effect of firing the guns of the battery, situated in the compound adjoining that of the Observatory, on the Magnetometers in the Magnetial Observatory.*

Observations in detail, of magnetometers, &c., made during the battery practices.

* An application was made in September last for a special practice with the Battery, but as a Detachment of Artillerymen would have had to be sent down to Bombay for the purpose, the most economical course was to await the ordinary practices.

The shortest distance between any one of the magnetometers and the nearest gun is 300 feet.

Date.	Observer's Initials.	Observed effects of firing and general remarks.
		I.—Declination Magnetometer.
Jan. 9th	N	After firing first round a slight vertical oscillation of the magnetometer scale was observed, but no other motion either at the moment of firing or afterwards.
	N	Second round, as before.
	N	Third round, no change noticed on firing.
„ 10th	N	First round, no effect, at all, noticed.
	C C	Second round, no tremor was noticed on firing, but immediately after, the horizontal vibration was observed to be slightly increased and a slight vertical oscillation (less than 30″ in extent) of the scale to be introduced.
	Chr.	Immediately after third round a little further increase of horizontal vibration appeared.
	K	Fourth round, no change noticed.
„ 11th	N	First round of only 3 shots—slight vertical oscillation, nothing more.
	N	Second round, ditto.
	K	Third round, ditto.
„ 12th	N	First round, no effect noticed.
	N	Second round, ditto
	C C	Third round, scale-reading remained the same as before firing, also horizontal vibration the same, possibly a trifling vertical oscillation was introduced (less than 30″ of arc).
	N	Fourth round, not observed till ½min. after firing, when scale-reading was as before.
„ 17th	N	Third round, no change observed.
	C C	During fourth round, a scarcely perceptible horizontal tremor and vertical oscillation was observed, nothing more.

Date.	Observer's Initials.	Observed effects of firing and general remarks.
		II.—Horizontal Force Magnetometer.
Jan. 9th	K	First round, scale-reading slightly increased, and a very small vertical vibration produced. (No perceptible change of scale reading was noticed at the successive moments of firing.)
„ 9th	K	Second round, same effects, only, as before.
	K	Third round, no change noticed on firing.
„ 10th	K	First round, same effects as at first—vertical oscillation less than 30″ in extent.
	N	Second round, slight vertical oscillation observed, nothing more.
	C C	Third round, no tremor noticed at the moment of firing, but the scale-reading was slightly increased (say by 15″) and my impression is that the increase took place during the firing, though no *visible* motion distinct from the regular slow and now very small (only 30″) horizontal vibration took place.
	Chr.	Fourth round, no motion whatever noticed.
„ 11th	K	First round (of only 3 shots) ditto.
	K	Second round, as before.
	N	Third ditto.
„ 12th	C C	First round, no vertical vibration noticed, but a slight tremor on firing; the horizontal vibration appeared to increase after the first two shots (not more than 12″) but diminished again when the remaining three or four guns were fired.
	N	Second round, not observed till immediately after the firing when the scale-reading and swing were precisely as before.
	N	Third round, no change observed.
	N	Fourth ditto ditto.
„ 17th	N	Second ditto ditto (It is believed that the greater part of the vertical oscillation formerly observed was due to the observer placing his arm on the supporting pillar).

Date.	Observer's Initials.	Observed effects of firing and general remarks.
Jan. 17th	C C	Third round, no change observed.
	N	Fourth ditto ditto.
		III.—Vertical Force Magnetometer.
Jan. 9th	G	First round, no change observed.
	C C	Second round, no motion observed on firing nor any change of scale reading, but from weariness of the eye in watching an uncertainty of 4″ might exist in estimating the position of the reading wire.
	C C	Third round, no effect observed.
„ 10th	C C	First round, a very slight decrease of scale-reading (about 12″) since a few minutes before 1st round, but there was no visible motion of the magnet on firing.
	Chr.	Second round, 1st two shots, no change observed.
	Chr.	Ditto 3rd to 5th shots, ditto.
„ 11th	G	First round, of 3 shots, ditto.
	G	Second round, ditto.
	Chr.	Third round, ditto.
„ 12th	C C	Second round, not the least tremor observed nor any effect except perhaps a very small increase of vibration.
		Fourth round, not observed during firing, afterwards the scale-reading was same as before.
„ 17th	K	Third round, no change observed.
	K	Fourth ditto.
		IV.—Collimator fixed on Declination Telescope pillar and observed by Theodolite placed on the same pillar.
„ 9th	Chr.	First round, no effect observed.
	Chr.	Second ditto ditto.
	Chr.	Third ditto ditto.
„ 10th	Chr.	First ditto ditto.

Date.	Observer's Initials.	Observed effects of firing and general remarks.
Jan. 10th		Second round, not noticed while firing, afterwards the scale-reading was same as before.
		Third round, no change effected.
	C C	Fourth round not the slightest visible tremor or change of any kind during the firing.
		V.—Theodolite removed to a separate wooden pillar.
„ 11th	Chr.	First round, no change.
	Chr.	Second ditto.
	C C	Third round, not the least tremor or motion visible.
„ 12th		First round, no change.
		Second ditto.
		Third ditto.
	C C	Fourth round, not the least motion or change.
„ 19th	N	*VI.—Theodolite placed on Declination Telescope pillar and pointed towards a mark on the wall surrounding the well: no change nor any effect produced by the firing.*

The windows of the Magnetical Observatory were violently shaken at all times, and occasionally loose panes of glass where shaken out.

5. *Remarks on the significance of the observations.*—It might reasonably be presumed that if any effect should follow the firing of the guns, it would not be by disturbance of the foundations of the Magnetometer pillars, but rather by the violent agitation of the air in the room being communicated to the exposed parts of the instruments; and this presumption is borne out by the observations, for the Series IV., V. and VI. show that no perceptible change was effected in the position of the isolated Declination Telescope pillar

On the probable mode of communication of disturbance, if occurring.

as compared respectively with another part of the same pillar with the floor of the room, and with the wall surrounding the well; and the Series III. proves that there was no permanent vertical motion (and probably no motion at all) of the isolated Vertical Force Magnetometer pillar. The very small horizontal and vertical vibrations of the Declination and Horizontal Force Magnets may, I think, be properly attributed to agitation of the instruments produced by concussion of the air in the room, especially as these are the only instruments which, by the nature of their construction, are liable to disturbance of this kind, the Vertical Force Magnetometer being (unlike them) completely protected from the external air and (though it is a less delicate indicator) we find accordingly that no sensible effect is produced upon it, in any way, by the firing of the guns.

Explanation of effects actually observed.

6. The very small but still appreciable increase of scale-reading which has sometimes been observed in the Horizontal Force Magnetometer, I am disposed to regard as real, but to attribute it also to the agitation of the air and the unprotected form of the instrument.

7. In conclusion, I am convinced that there is no ground to fear any objectionable disturbance of the basement pillars of the Magnetometers, and that by carefully closing up the room in which the proposed new Magnetographs are to be placed, and remembering that the latter are further protected from the air by being enclosed in glass shades, the gun practices may be expected to leave the minutest trace, if any at all, of their influence upon the self-recording Magnetometers.

Conclusion.

8. The observers initials refer to—

C. C.—Mr. Chambers, Superintendent.

N.—Mr. Naro Balcrishna, 1st Assistant, Magnetical Department.

K.—Mr. Keshow Pandoorung, 2nd do. do.

G.—Mr. Gunesh Narayen, 1st Observer.

Chr.—Mr. Crishnajee Gunesh, 2nd do.

Reason for giving observations in detail.

9. The great importance of these experiments (whether viewed as determining more exactly the value to be attached to the observations made since the first trial of the battery, or) in furnishing conclusive evidence shewing that the objection to the present situation of the Magnetometers may be safely disregarded, has induced me to describe them in some detail and thereby to furnish means for the exercise of an independent judgment. Had there been no means of testing the weight of the objection, it would doubtless have been unwise to continue an elaborate system of delicate observations on a site which gives such good *a priori* grounds to suspect occasional deviations from absolute fixidity of the instruments, and though the observed result is astonishing when compared with the sensation produced on the firing of the guns, yet it is so decided that no doubt remains on my mind of the suitableness of the present site of the Magnetical Observatory.

Objection not of consequence, as regards Magnetometers.

Any movement of the instruments due to firing might be eliminated from records of proposed magnetographs.

10. Moreover, it is to be remarked that while any disturbance of the Magnetometer pillars would with the present instruments have its full effect upon the observations and be incapable of elimination, this would not be the case with the self-recording magnetographs recommended to supercede the hourly system of observation, for in these every slight change of pillar or magnet or both would be traced photographically and be capable of exact measure-

ment at leisure, and thus the continuity of the records before and after the disturbance might easily be restored.

Unlike present instruments, those proposed are not liable to be affected by concussion of air.

11. It was remarked that the slight movements of the magnets which were observed during the firing of the guns, were believed to be due to the vibration of the air acting upon the exposed parts of the instruments; in the self-recording instruments no effect would follow from this cause, as the magnets are supported entirely from within an enclosure which is protected from the influence of any motions in the outer air.

Enquiry extended to effects of firing on chronometers, &c.

12. As a suspicion of injury to the chronometers in store at the Observatory is included in the Committee's objection to the vicinity of the guns, it is considered advisable to extend the enquiry to the actual effects of the firing both on the transit instrument, clocks and chronometers.

Results of observations.

13. It will be seen from the following observations of the transit collimator before the commencement and after each day's practice, that although the nearness of the guns to the Astronomical Observatory is more objectionable than in the case of the Magnetical Observatory, it is not so to such an extent as materially to affect the practical purposes which this Department has to serve. The comparisons of the observed rates of clocks and chronometers before, during and after the time occupied by the practices shew no effects attributeable to the firing.

Errors of transit instrument before, during, and after battery practices.

14. *Results of measurements of the errors of the large Transit Instrument after each day's practice with the battery, obtained by viewing with it a collimator*

mark, at a distance of 35 feet, which is moveable by a micrometer screw:—

1866 Date.	Level error.	Collimation error.	Azimuthal error. Supposing position of Collimator invariable.	Azimuthal error. By observations of Polaris and other stars.	Azimuthal error. Calculated *minus* observed.
Jan. 2nd	+ 6″·7	+ 3″·1	+ 9″·6	+ 9″·6	0″·0
10th	+ 7 ·2	+ 14 ·8	+ 9 ·3		
11th	+ 6 ·2	+ 48 ·1	+ 11 ·4		
12th	+ 6 ·9	+ 48 ·7	+ 12 ·6		
13th	+ 4 ·5	+ 45 ·7	+ 9 ·9	+ 5 ·4	+ 4 ·5
17th	+ 6 ·9	+ 47 ·4	+ 7 ·8		
18th	+ 5 ·5	+ 46· 6	+ 9 ·7		
19th	+ 2 ·7	+ 46· 6	+ 8 ·8	+ 12 ·9	— 4 ·1
* 22nd			— 57 ·0		
23rd	+ 3 ·7	+ 47 ·2	— 57 ·0	— 53 ·7	— 3 ·3
24th	+ 2 ·5	+ 47 ·7	— 65 ·9		
* 24th			— 3 ·8		
25th	+ 1 ·8	+ 48 ·0	+ 2 ·5	+ 12 ·4	— 9 ·9
26th	+ 3 ·1	+ 46 ·6	+ 3 ·2	+ 9 ·9	— 6 ·7
27th		+ 47 ·7	+ 4 ·3		

15. Disregarding for a moment, the first two Collimation errors given above, it is seen that from the 2nd to the 19th January the limits of variation of Level, Collimation, and Azimuthal errors lie respectively within 4″·5, 3″·0 and 7″·5, and these may be regarded as the maximum disturbing effects of the firing of the guns so

Explanation of changes shown by table.

* Azimuthal adjusting screw turned during these intervals. The Collimator was frequently observed by the transit instrument at the moment of firing and a slight tremor (probably not exceeding 2″) was noticed.

long as the instrument remained under the same condition as to the position of its adjusting screws. The series of Collimation errors show that the wire plate of the Transit instrument was displaced by the firing on the 9th and 10th of January, but remained sensibly in the same position from the 11th to the 27th. The movements on the two first days will create no surprize, when it is explained that it was afterwards discovered that one of the adjusting screws of the wire plate was so much worn that it could be turned completely round without producing any motion of the plate; the shock produced by the firing caused the screw to slip, and the wire plate being relieved from the slight strain by which it was previously held, moved a little in the direction receding from the worn screw. In agreement with this supposition as to the cause of the change, the defective screw was on the eastern side of the transit instrument and the wire plate moved to the westward. The Azimuthal adjusting screw of the Transit instrument had long been disused, on account of its not being firmly fixed. A motion of 4′ in Azimuth was possible without any altertion being made upon the screw, it is therefore easy to see that the comparatively large changes (8″·9 and 6″·3) of Azimuthal error produced by the firing on the 23rd and 24th January, after the adjusting screw had been freshly turned, would probably have been avoided but for this fault of the instrument, which has now been remedied.

16. The limiting range of differences between the Azimuthal errors obtained from observations of Polaris and other stars and those deduced from the readings of the Collimator is 14″·4, which is about the same as the variation of the position of the Collimator mark which was possible from the play of the Collimator object-glass-frame in its screw fitting; but another fault of the Collimator was discovered which would account for much larger changes of the position of the mark without supposing any motion of the supporting pillar to have occured: this was that the screw-piece which should fix the object-glass in its frame had been put

on awry, so that it could not be screwed home, and the glass was free to shake about and change its position upon its being subjected to the slight jerk which attended the firing. This has now been put right and I have no doubt that when the next experiments are made, the Collimator will be found to agree very closely with the independent observations of stars for Azimuthal error.

Changes observed believed to be due to instrumental imperfections, now remedied.

17. The changes produced by the gun practices shown in the foregoing table, I believe to have been due principally to instrumental defects which have now been remedied, and that neither the supporting pillar of the Transit instrument nor that of the Collimator were appreciably disturbed; this view is supported by the fact that a small theodolite, which was placed in one of the window recesses of the Time-Ball Tower and pointed towards Colaba Church spire (half a mile distant) was unaffected.

Changes produced by firing being easily measurable, may be allowed for, and so are unimportant.

18. As regards the influence of these changes upon the determination of time, those of Level and Collimation are of no consequence as they can easily be measured after each practice; and the same may be said of Azimuthal changes if, as I believe, the Collimator may now be assumed to be practically unvariable. And since the same opportunities of observing the Azimuthal error independently of the Collimator, will be available during the gun practices as at other times, the degree of accuracy attainable will also be the same.

Collimator mark belived to be now practically unvariable.

19. Comparison of the mean daily rates of Chronometers and Astronomical Clocks at the Government Observatory before, during, and after the Practices with the Colaba Battery in January 1866.

Register Number.	Distinguishing marks of Chronometers, &c.		Mean rates before commencement of the firing.				Mean rates while the firing continued.		Mean rates after conclusion of the firing.				Mean rate for the four weeks immediately preceding the firing.	Mean rate for the two weeks during which the firing continued.	Mean rate for the four weeks immediately following the firing.
	Maker's Names.	Numbers.	1st week.	2nd week.	3rd week.	4th week.	1st week.	2nd week.	1st week.	2nd week.	3rd week.	4th week.			
Number of Column	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	James McCabe	299	— 4·2	— 3·7	— 4·0	— 3·8	— 3·8	— 3·6	— 4·4	— 3·5	— 3·1	— 3·3	— 3·92	— 3·70	— 3·57
2	James McCabe	319	+ 7·9	+ 7·8	+ 8·1	+ 8·6	+ 8·2	+ 8·4	+ 8·0	+ 9·0	+ 9·7	+ 9·1	+ 8·10	+ 8·30	+ 8·95
3	Parkinson and Frodsham	3628	+ 4·2	+ 3·7	+ 4·0	+ 4·5	+ 3·6	+ 3·4	+ 4·1	+ 4·7	+ 4·8	+ 4·3	+ 4·10	+ 3·50	+ 4·47
4	John Campbell	813	+ 2·3	+ 1·6	+ 2·1	+ 2·6	+ 3·2	+ 3·0	+ 2·6	+ 3·0	+ 3·2	+ 2·5	+ 2·15	+ 3·10	+ 2·82
5	Parkinson and Frodsham	2400	— 7·6	— 7·8	— 7·6	— 7·5	— 7·1	— 7·2	— 7·2	— 7·1	— 6·8	— 6·8	— 7·62	— 7·15	— 6·97
6	Do. do.	3684	— 3·4	— 2·4	— 2·6	— 2·2	— 2·4	— 2·3	— 2·3	— 2·0	— 1·3	— 2·2	— 2·65	— 2·35	— 1·95
7	John Carter	524	+ 16·5	+ 17·1	+ 16·7	+ 17·4	+ 17·3	+ 17·1	+ 18·0	+ 17·8	+ 18·6	+ 17·4	+ 16·92	+ 17·20	+ 17·95
8	Do.	540	+ 6·6	+ 5·2	+ 6·2	+ 6·6	+ 6·1	+ 6·6	+ 6·0	+ 5·0	+ 5·1	+ 6·2	+ 6·32	+ 6·35	+ 5·58
9	Dent	2832	+ 9·2	+ 9·0	+ 8·6	+ 8·6	+ 8·5	+ 8·6	+ 8·2	+ 9·3	+ 9·5	+ 9·0	+ 8·85	+ 8·55	+ 9·00
10	Thomas Roberts	1163	— 0·8	— 1·1	— 0·2	— 0·7	— 0·6	— 0·7	— 0·5	— 0·5	— 0·4		— 0·70	— 0·65	— 0·47
11	John Lawson	1391	— 2·8	— 2·2	— 2·2	— 2·8	— 2·3	— 2·2	— 2·7	— 2·0	— 2·0		— 2·50	— 2·25	— 2·23
12	Cameron	1711	— 3·0	— 3·0	— 2·9	— 3·1	— 2·9	— 3·2	— 3·5	— 2·6	— 3·0		— 3·00	— 3·05	— 3·03
13	A. Walker	644	+ 7·3	+ 7·1	+ 7·4	+ 7·3	+ 8·0	+ 7·6	+ 7·9	+ 7·2	+ 7·7	+ 7·8	+ 7·37	+ 7·80	+ 7·65
14	G. Gowland	314	+ 6·9	+ 7·4	+ 7·3	+ 7·4	+ 7·0	+ 7·5	+ 7·6	+ 7·4	+ 7·8	+ 7·5	+ 7·25	+ 7·25	+ 7·58
15	A. H. Rose	158	+ 1·5	+ 1·8	+ 1·7	+ 2·0	+ 1·9	+ 1·6	+ 1·7	+ 2·5	+ 2·5	+ 2·9	+ 1·75	+ 1·75	+ 2·40
16	John Poole	3794	+ 1·1	+ 1·6	+ 1·4	+ 1·7	+ 1·5	+ 1·6	+ 1·7	+ 1·8	+ 2·3	+ 1·5	+ 1·45	+ 1·55	+ 1·82
17	Barraud	2869	+ 3·8	+ 3·0	+ 3·0	+ 3·8	+ 4·0	+ 4·1	+ 4·0	+ 4·0	+ 4·9	+ 4·0	+ 3·40	+ 4·05	+ 4·22
18	Dent	23696	— 4·8	— 4·0	— 5·0	— 4·0	— 3·8	— 4·2	— 4·1	— 3·3	— 2·5	— 3·5	— 4·45	— 4·00	— 3·35
19	Charles Shepherd	1582	+ 1·1	+ 1·9	+ 2·3	+ 2·3	+ 2·3	+ 2·0	+ 2·0	+ 1·5			+ 1·90	+ 2·15	+ 1·75
20	D. McGregor	191	— 1·3	— 0·5	— 1·2	— 0·8	— 0·5	— 0·6	— 0·0	— 0·5			— 0·95	— 0·56	— 0·25
	Mean rate of the 20 Chronometers		+ 2·02	+ 2·16	+ 2·15	+ 2·39	+ 2·41	+ 2·37	+ 2·35	+ 2·58					
	Astronomical Clocks.														
	Sidereal Clock		— 5·63	— 5·48	— 5·60	— 5·39	— 6·10	— 6·12	— 6·33	— 5·60	— 6·20	— 6·40	— 5·52	— 6·11	— 6·18
	Mean Time Clock		— 2·7	— 2·5	— 2·5	— 2·4	— 2·2	— 2·8	— 3·2	— 2·7	— 2·0	— 2·6	— 2·52	— 2·50	— 2·62

20. No chronometer was excluded from the comparison, whose rate was moderately regular previously to the commencement of the firing, this being the only criterion used in the selection.

Adopted true times were not erroneous.

The regularity of the mean numbers at the foot of the several columns implies that the inferior degree of regularity in the rates of some of the individual chrometers, during the four weeks before and after the firing, was due to real faults of the instruments, and not to errors in the adopted true times, since in the latter case the irregularities would have re-appeared in the mean values and in the same degree as in the individual instances. Knowing then that such imperfections exist in the instruments, it is not to be expected that the mean rates during the firing will exactly correspond to those found before and after it, even if the gun practices had no effect whatever on the chronometers. But it will be useful to compare the amount of the discordances in these rates with the extent of the deviations from uniformity in the rates during the four weeks immediately preceding or during the four weeks following the firing, because if the former are found to be very inferior in amount to the latter, they may reasonably be supposed to be included under the latter, and thus attributable to the same causes:—if it were demanded however that the whole of the former discordances should be assumed to be produced by the firing, the comparison will still enable us to estimate the proportion of this effect to that due to the ordinary imperfections of the instruments, and thus indicate whether it is of such a nature as to call for serious attention. In the following table the first line of figures shows the maximum difference between any two numbers in columns 4 to 7 or in columns 10 to 13 of the preceding table, and represents the ordinary irregularities of the instruments, while the numbers in the second line are the differences between those in column 15 and those in columns 14 or 16, and these represent the observed effects that are assumed (for the

Comparison of changes during firing with those due to instrumental imperfections.

moment) to be caused by the firing. The numbers at the head indicate the particular instruments according to their register numbers in the preceding table.

21. Table showing (under the improbable assumption of the observed change of rate being entirely caused by the gun practices) the relative effects of the firing of the guns as compared with the effects of ordinary instrumental imperfections.

Register number of Instrument.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Mean.
Effect of instrumental imperfections	1·3	1·7	0·8	1·0	0·4	1·2	1·2	1·2	1·3	0·9	0·7	0·9	0·7	0·5	1·2	0·6	0·9	1·6	1·2	0·8	0·7	1·2	1.00
Assumed effect of firing	0·22	·65	·97	·32	·47	·30	·75	·03	·45	·05	·25	·02	·15	·33	·65	·27	·17	·45	·40	·40	·02	·12	·34

22. It is seen that in only two out of the twenty-two instances is the lower number greater than the upper, while in the mean values it is only one-third of the upper number. Thus it appears that under ordinary circumstances, when no firing takes place, the irregularities of the rates of the best Chronometers are three times as great as those which may, under the most unfavourable assumption, be considered as the result of the firing,—and further the same evidence renders it probable that the change of rates observed during the period of the gun practices was the result of the same causes that produced the larger irregularities found before and after the gun practices and was not at all due to the firing. Hence I think that no argument for the removal of the Observatory can stand on this ground.

Rates of Chronometers &c. probably not affected by battery practices.

23. While treating of this point, it will be well to indicate the class of this Observatory, as it may be inferred from the last twenty

Character of Observatory, as shown by past operations, defined.

years' observations, a little more closely than is shown by a simple enumeration of the several operations its organization embraces, especially as it appears from Colonel Marriott's letter (Marine Department, No. 548) dated 28th July 1864, that this is one of the considerations which Government wishes to have attended to in suggesting improvements. First then, it may be remarked that the system of hourly Magnetical and Meteorological observations has formed for the last twenty years the most marked feature of its proceedings as a strictly scientific institution, and this feature it has possessed in common with a number of other Observatories widely distributed over the British Colonies, which were established by the British Government, on the recommendation of the Royal Society of London, at about the same time and with a common object in view. The only other observations of a systematic and scientific nature made during the same period are those of the tides, and as these are automatically recorded the attendance of the observer is needed, under ordinary circumstances, but once a day and the labour involved is slight compared with that of making the numerous hourly observations.

24. The purposes served by the time observations made in the Astronomical Observatory have been almost exclusively practical, viz:—for dropping the Time Ball and rating Chronometers. For providing time for the use of the Magnetical Observatory a much less elaborate system of observation would suffice than is required for the other purposes mentioned, and these again need not the precision that would be essential for the satisfactory record of general Astronomical phenomena.

25. It is clear then, that as a Scientific Observatory it has been chiefly Magnetical, Meteorological and Tidal, and scarcely at all Astronomical, there being no systematic Astronomical observations at Bombay on record, while the accumulation of Magnetical and

The Scientific proceedings of the Observatory have been Magnetical, Meteorological and Tidal, while the recorded Astronomical operations have been almost exclusively practical.

Meteorological data has been most sedulously continued for a period of upwards of 20 years. From the latter there is already good reason to believe that by a proper, though generally laborious and lengthy, treatment much valuable information which at present lies hid in the observations may be extracted.

The combination of extensive Astronomical operations with those of magnetism and meteorology unadvisable.

26. Moreover, it is the professed opinion of most eminent physicists that the successful working of either a high-class Astronomical or Magnetical and Meteorological Observatory requires the undivided energies and devotion of its director, and that when the two are combined one suffers by his naturally pursuing more zealously that subject in which he feels most personal interest.

Madras holding high rank in Astronomy, it remains for Bombay to cultivate the fields of Magnetism and Meteorology.

For the future it is rather therefore for Bombay to take the lead as the Central Physical Observatory of India and leave to Madras the field of Astronomy in which she has long held a high reputation.

Battery practices will not interfere with practical operations of Astronomical Observatory.

27. If, then, it be allowed to be a wise course to continue to subordinate the Astronomical to the other departments of the Observatory, the effect of the firing of the guns upon the Transit instrument is of no importance, so long as it can be measured and the time deduced with sufficient accuracy for the practical operations of dropping the Ball and comparing Chronometers. That an ample degree of accuracy is attainable is shown by the observations during the gun practices given above, but it may be well to give an idea here of what is practically a sufficient degree of accuracy. It may be safely assumed that the average stay of a Merchant ship in the harbour exceeds one month so that Chronometers nearly always lie in the Observatory for comparison beyond that time; now let us suppose there to be an

uncertainty in the observed change of the error of the Chronometer during the month to the extent of 0·5 second, this would produce on the daily rate an uncertainty of less than 0·02 second, and as the rate commonly used by seamen is carried only to the first place of decimals, the assumption involved in this practice, viz. that sufficient accuracy is attained by it, may allow greater uncertainty (viz. 0·05 second) than can possibly arise from error in the determination of the rate due to irregularities of the Transit instrument even during a month in which repeated practices with the guns take place. Even allowing an error of 1·0 second (twice as great as is supposed above) a ship could not be out of reckoning at the end of a 3 months' voyage so much as one mile, and besides it would be over-refining to seek extreme accuracy in this respect, when from the necessary inperfection of construction of Chronometers, the irregularities almost invariably found in the actual rates produce much greater errors.

Error in a ship's reckoning (caused by firing of guns) after 3 months' voyage could not reach one mile.

Errors from imperfect construction of Chronometers much greater.

28. Again, it is not to be presumed that the battery practices will commonly take place simultaneously with the occurrence of special Astronomical phenomena which it may be desirable occasionally to observe here.

29. The proximity of the guns does not therefore appear to be of consequence as regards any of the operations of the Astronomical Observatory.

30. As to the other objection to the present site advanced by the Committee, viz. that it is not adapted for directly ascertaining the general meteorological phenomena of the Island of Bombay, it must be remembered that in planning a grand scheme like that of the British Colonial Observatories, of

Other objection to present site.

Bombay one of the stations in the grand scheme of the Colonial Observatories.

which it has already been said that the Observatory of Bombay formed a part, the great object aimed at in the selection of the stations would be, next after their being widely separated, that the meteorology of any one should represent generally that of as large a portion of the globe surrounding it as possible, and with this view any influences of a strictly local character would be carefully avoided. This is seen from the variety, viewed on a grand scale, of the localities selected:—the Observatories of Toronto and Simla were far removed from the sea; that of St. Helena is closely surrounded by it; of Hobarton near the coast of a small Island; while those of the Cape of Good Hope, Madras and Bombay are in immediate proximity to the sea and bordering on Continents. Viewed from this point it is not easy to see the *a priori* reasons why any other part of the Island should be preferred to the Colaba Point which is fully exposed to changing influences whether they proceed from the sea or land; besides no single station could be assumed to represent Meteorologically every part of the Island, and it is to be hoped that, as public interest becomes awakened to the subject and assistance is rendered from the Observatory, the desired object will be attained, as is the case in Great Britain, by the combined labours of private observers. For Sanitary purposes observations might be made (say) four times a day at some spot in the Native Town or its neighbourhood, fixed upon by the Public Health Officer, at an expense of 50 or 60 Rupees per month, and these combined with the observations taken at Colaba would probably afford information more to the purpose, than if the Observatory were transferred to another locality probably no better suited than the present to the object in view.

Strictly local influences avoided.

Any other situation liable to similar objection.

Observations required at several points on the Island to afford a general knowledge of its Meteorology; these should be obtained by the aid of amateur observers.

Observations for Sanitary purposes might be made on a limited scale in the Native Town or its neighbourhood.

31. To conclude this question, although it would doubtless be blameable, if the site of the Observatory were to be determined upon for the first time, to place it near a battery of heavy guns of which it might be presumed as probable that they would act injuriously upon the instruments, yet as the result of careful experiment the conclusion appears unavoidable, that neither the present nor the projected operations of the Observatory, in any of its branches, require, in such a sense as to justify the expenditure that would be involved in the erection of new buildings, that the Observatory should be removed from its present situation. There is on the other hand, a consideration connected with the vicinity of the battery that would counsel the removal of the Observatory; in the event of an engagement between the battery and an enemy's ships in the harbour, the fire of the latter would probably cause much damage to, or even destroy, the Observatory buildings, and thus interrupt the observations; the question then becomes, is the probability of the occurrence of a maritime war and the consequent stoppage of the operations of the Observatory, so great as to render it advisable rather to incur the heavy charge of building a new Observatory, than to add about Rupees 9,000 to the cost of the present buildings to fit them for their new purposes; and this question I beg to defer for the consideration of Government. In what follows, without holding any strong opinion on the subject on other grounds than economy, I have, in order to avoid delay in the separate submission of this question, proceeded on the assumption that the latter is the preferable course.

Removal of Observatory not required by any of present or projected operations.

Probability of a maritime war and consequent destruction of Observatory to be weighed against large outlay required for new buildings.

Part II.

On the improvements requisite for the efficient working of the Establishment and for the extension of its operations.

Improvements required.

32. It is desirable to recall attention here to what has been said (in paragraph 23) as to the general character of the Observatory, as shown by the objects hitherto mainly pursued, and to remark that so far as it has failed to take high rank among similar institutions, it has been due, as may be gathered from a great portion of the Report of the Committee, not so much to its labours having been directed into wrong channels as to the injudicious manner in which those labours have been conducted.

Complete and correct registration of Magnetical and Meterological phenomena of first importance.

Assuming then that the proper functions of the Observatory will continue, in the main, the same as hitherto, the complete and correct registration of Magnetical and Meteorological phenomena claims our first attention, and it is important to observe that while the changes of the different elements of Terrestrial Magnetism are sometimes enormously large and rapid as compared with ordinary variations, so much so, that it is at times absolutely impossible to mark every feature of change by personal observation, some of those of Meteorology may almost always be traced with much accuracy by eye-observations, and some are very imperfectly represented in this way. It has consequently become almost the universal practice in more modern Observatories to use self-recording instruments for the continuous registration of Magnetical and the more variable Meteorological phenomena; and it seems to be strongly advisable that similar means should be adopted at Bombay. The minute delineation of the variable Magnetic Forces (of which it may be said that the

Self-recording instruments needed for the more variable phenomena.

large and extraordinary disturbances alluded to possess scarcely less interest for the student than do the regular variations,) especially demand this. The appended copy of a curve obtained during a Magnetic disturbance at Kew Observatory will shew the force of the remark as to the impossibility of tracing such curves accurately by eye-observations and will serve to illustrate some of the following observations on the advantages of this method of registration over that practised at the present time at Bombay. If then it be desired that Bombay should hereafter stand creditably in comparison with other physical Observatories it is manifest that the instrumental means used for the record, especially of Magnetical phenomena, should not be less perfect than is available elsewhere; for this reason, and on account of the inherent advantages of the method of continuous self-registration by photography, I deem it of the highest importance that the Observatory should be provided with a set of Magnetographs of the kind recommended by the Kew Committee of the British Association for the Advancement of Science and verified at their Observatory at Kew. This and the alteration of the interior of the present Magnetical Observatory to suit it for the reception of the instruments, together with some internal alterations to another existing room to fit it for the necessary photographic operations will form the most considerable, in point of magnitude, of the improvements needed.

Specimen curve obtained from magnetographs appended.

A set of Kew magnetographs should be provided, and the Magnetical Observatory be altered for their reception: these and arrangements for photographic operating room are the most costly alterations required.

33. As an indication of the degree of importance attached by scientific men in various parts of the world to the work of well-conducted Magnetical Observatories, and as testifying the high estimation in which the Magnetographs and other instruments supplied under the direction of the Kew Committee are held, it may be well to enumerate the establishments that have been

Evidence of importance attached to use of Kew Magnetographs.

equipped from the Kew Observatory between the years 1860 and 1863 with complete instruments of the description recommended for Bombay.

	Name of station.	Name of Government.	Name of Director of Observatory.
By foreign *savans.*	Batavia, Java	Holland	Dr. Bergsma.
	.....	United States	Dr. Bache.
	University of Coimbra.	Portugal	Profr. DeSouza.
	Lisbon	Do.	Senhor da Silva.
	St. Petersburg	Russia	Profr. Kupffer.
	Florence	Italy	Profr. Donati.

By Royal Society and British Association.

To the same effect are the resolutions come to by a joint Committee of the Royal Society and of the British Association in 1859, to recommend to the British Government the establishment and maintenance of four new Magnetical and Meteorological Observatories at Vancouver Island, Newfoundland, the Falkland Isles and in or near Pekin. (Report of the British Association, 1859. P. XXVIII.)

Advantages of photographic self-registering magnetometers over the antiquated instruments used at present.

34. Some of the advantages attending the use of the photographic self-registering magnetometers may be here recounted.

1. In view of possible applications of the records to be made in trying physical theories, it cannot be of little consequence that the records should be continuous, giving the magnetic forces for every successive moment of time, instead of their being limited to 24 momentary values on each day.

2. This permits the measurement of the ordinates of the photographic curves at points corresponding to the absolute time (in hours or otherwise as may be thought desirable) of any given meridian or to local or apparent, solar or lunar time.

3. It also obviates the loss of observations on Sundays and holidays, and will hereby increase the value of the results arrived at by one-sixth at least.

4. Moreover in substituting mechanical agency for the personal watching of the observer, through the long hours of night, (a labour necessarily attended by much weariness, which to some extent unfits him for the most satisfactory execution of his functions), some advantage will be gained in point of accuracy.

5. There is also reason to believe that in obviating the frequent opening and closing of the doors of the magnetometer room, greater purity of the results is obtained.

6. With regard to magnetic storms, complete and simultaneous records, for at least two distant stations on the earth's surface, are required for the effectual investigation of some points of interest relating to the nature of the disturbing forces, and it is only by the aid of photography that every detail of a disturbance can be preserved.

7. And further the prominent features of a disturbance are seen at once by a glance at the photographic trace, while they might easily be missed in the case of eye observations, if, as is frequently the case, the latter were not afterwards curved.

8. Two eminent magneticians have given some countenance to the theory which regards electrical earth currents as causing the observed variations of the earth's magnetism. Evidence bearing on this point whether positive or negative is therefore

valuable, and the best materials for affording this evidence, viz. magnetic storms, would be too imperfectly recorded by eye observations to allow the comparison to be made satisfactorily.

9. Several advantages also arise from the use of small magnets in the construction of the proposed instruments.

(1.) Currents of air circulating in the magnetometer box will have less influence the smaller the length of the bar.

(2.) On the occurrence of a sudden disturbing force, the needle is set swinging, but as the small magnet (on account of the smaller ratio of its moment of inertia to its magnetic moment) moves more rapidly than the large, it is more opposed by the reaction of the electrical currents induced in the surrounding copper damper, as well as by the air, and comes to rest more quickly; thus it is capable of indicating disturbing forces of shorter duration than the large magnet, since the latter would not have ceased to swing when a new disturbing force was impressed upon it.

(3.) The different parts of the apparatus are more easily handled in making adjustments.

10. The knife edge of the Balance Magnet rests upon a single agate plane, whereas the present vertical force magnet has two agate supports, which require a difficult adjustment to bring them into the same horizontal plane; and any fault as to the identity of the planes in which they are left is likely to produce irregularities in the observations, from which those made with the new form of this instrument are free.

Use of gas with photographic instruments essential.

35. The use of gas is essential to secure uniform success in the working of these Instruments, and it happens very opportunely that before the instrumental and other arrangements can be com-

pleted, the Bombay Gas Company will be in a position to supply it. An estimate of the expense of introducing gas into the Observatory is therefore included in the Statement at the end of this Report.

Other instrumental improvements required.

36. As to the desirableness of improved means of registering the following Magnetical and Meteorological phenomena, it is perhaps needless to enlarge upon the reasons advanced in the Report of Observatory Committee:—

Magnetic Dip,
Absolute Magnetic Declination,
Direction of Wind,
Force of Wind,
Barometric Pressure,
Atmospheric Electricity,
Ozone.

The first five of these will be provided for by the new instruments included in Indent dated the 28th October 1865, the supply of which has received the sanction of the Home Government, and the two last by the instruments Nos. 2 and 5 of the list appended to the Report. With respect to atmospheric electricity, the observations made when treating of magnetic disturbances (paragraph 32) are applicable with even greater force here, the amount and rapidity of change even under ordinary circumstances being so great as to render continuous self-registration the only practicable means of preserving a record of even the prominent features of the variations of this element. In corroboration of this opinion, I may refer to a statement made by the Astronomer Royal in his Report to the Board of Visitors of the Greenwhich Observatory in 1864 (page 18). Referring to instruments for observing atmospheric electricity, similar to those in

The greater part sanctioned and instruments ordered by Home Government.

Electrometer should be self-recording by photography.

use at Bombay, he says 'until satisfactory means of self-registration can be arranged, these instruments are nearly useless.'

Transit instrument needs repair and protection from weather.

37. In the course of about 25 years' wear the axis of the Transit instrument appears to have acquired so much irregularity of figure, indicated by differences of level observations with different elevatitons of the Telescope, as to render it desirable that it should be newly turned as well as its bearings: the level pivots also require the same treatment, and the level and azimuthal adjustments need thoroughly cleaning from rust, and a new glass wire-plate is wanted; also a removeable protecting cover is required over the instrument to carry off rain that leaks through the Transit opening in the roof of the Observatory during the monsoon. The repairs of the instrument may be effected at a cost of about Rupees 150 and the construction of the protecting cover at Rupees 65.

Repairs may be executed in the Indo-European Telegraph workshop at Kurrachee.

38. Government possess, in the well furnished workshop of the Indo-European Telegraph Department at Kurrachee, which is at present in charge of a most skilful mechanician (Mr. Ludwig Dolitzscher), a convenient and satisfactory means of effecting repairs which require great delicacy and perfection of workmanship, like those just mentioned; and having reason to believe that the Director of the department would very willingly endeavour to afford the advantage to the Observatory, that would accrue from the workshop and the services of Mr. Dolitzscher being available for repairs and alterations of instruments, I would respectfully request the sanction of Government to this arrangement, as well with respect to the minor repairs, alterations, and additions, that may from time to time be found needful, and be chargeable under a regular small contingent grant for this purpose,* as for the repair of the Transit instrument. As the

* The Committee of Enquiry remark in para 35 of their Report "the instruments employed ought not only to be really good ones, but it is as necessary that they should be preserved in a state of constant repair."

means of communication between Bombay and Kurrachee are both frequent and safe, such an arrangement would be attended with advantage, over the plan of sending the instruments to England, not only in the saving of time but also by diminishing the risks of injury to the instruments in transit.

Additions required to Library.

39. The defective state of the Library calls for remark here—for while several valuable collections of observations are contained in it, as well as the transactions of some of the learned Societies, there is an almost entire lack of a very important class of books of reference for an institution of this character, viz. of standard treatises on the different branches of physical science. To meet a portion of this deficiency both for general purposes of reference and for the instruction of the *employès* of the Observatory, I would respectfully suggest that a sum of Rupees 120 should be granted for the purchase of books, especially of works on the sciences in whose interest, chiefly, the Observatory is maintained.

Present Establishment will be able with a little pressure, to work the Photographic instruments.

40. By means of photography a great saving of labour will be effected in the actual production of the records of magnetical and electrical phenomena which will at the same time be infinitely more complete than under the present system, but while this undoubted advantage is gained, it is necessary, before calculation can be applied, that the photographic traces should be converted into numerical form, involving an amount of labour differing little, except in the greater convenience of the time of applying it, from that undergone at present. And as the regular reductions will henceforth be more tedious than they have been, the strain of work upon the Staff of Assistants will accordingly be increased. But as the irksome night duty will be abolished, it is fair to expect greater diligence from the assistants than heretofore and the photographic operations should

also be performed without increase of establishment. It appears advisable however to allow some increase of pay to the four hamals who are steady and trustworthy servants, and whose work will be heavier in consequence of the proposed changes. I would suggest that they should receive each Rupees 8 per mensem instead of Rupees 6 as at present.

Special body of computers required for the reduction of the old observations.

41. The complete reduction and discussion of the large body of old observations is a work, of considerable magnitude, which pressingly demands an early execution; I have therefore in the hope (and with good prospect) of obtaining an instalment of the value contained in them of sufficient interest to encourage a continuance of the work, devoted to this purpose, the small computing force at present available in the Observatory, although as a necessary consequence the current reductions will fall into arrears. It is besides a hopeless task to make much impression in this way upon an accumulation of 20 years' observations, which must be treated afresh generally from the very beginning of the processes of reduction, and I would therefore respectfully suggest that with the exception of the direction of the work and discussion of the results by the Superintendent of the Observatory, it should be regarded as a special undertaking for which a body of six computers, at an average salary of Rupees 40 per mensem, should be employed temporarily until the work is fully accomplished. There is already good reason to expect that it would yield a good return for the money and labour so spent; and the measure of success attending the first year's labours might be taken as a guide as to the further prosecution of the work. It is clear that so long as this is deferred much of the value of the past operations of the Observatory is lost to the world, and it may be inferred from the recommendation of the Royal Society and British Association (see para. 33) for the establishment of new Observatories, how strongly they would urge the completion, by a proper and thorough reduction

and discussion of the Observations, of the past work of the Bombay Observatory. In this respect, the result proves how wisely the British Government acted in establishing an Office in England, simultaneously with the Colonial Observatories, for effecting the reduction and discussion of the observations; this Office has been uninterruptedly maintained to this day and from it have proceeded nearly the whole of the large contributions that have been made in the last quarter of a century, to magnetical knowledge. (See Report of Committee of Enquiry, paragraph 52.)

Condition of Tide-guage.

42. Some months previous to my taking charge of the Observatory the Tide-guage had ceased to be serviceable owing to a breach in the iron pipe leading from the Tide-house to the sea. The possibility of such a pipe, the length of which is 780 feet, becoming partially obstructed, and unequally so at different times throws some doubt upon the comparability of the observations, and this together with the fact that the times and heights of the tides are in any case, modified by the interposition of the long tube between the actual sea level and the surface whose height is measured, render it advisable that a location should be sought for the apparatus where the sea would flow directly under it:—nothing could however be done in preparing for its removal until it was known whether the Observatory must needs be removed also, and when this was determined, I became convinced, on learning that the repair of the apparatus where it stands would cost so large a sum as Rupees 2,060 that it ought to be removed, since this sum, if not even sufficient for, would go far towards, paying the expenses of transferring the guage to a suitable situation. The Western side of the Oyster Rock Island is a locality well suited for Tidal observations; it is even considered by the Harbour Board to be the best in the harbour, and there appears to be no objection to the apparatus being placed

Its removal to a suitable locality advisable.

Such a locality is the Western side of the Oyster Rock, which may shortly become available.

there, but the designs for the fortifications not being yet completely fixed, it is impossible at present to say whether the small space that the apparatus would require could be allotted to it without interfering with the primary purposes of the Fort. This state of uncertainty it is, however, expected will cease very shortly, when a definite plan may be submitted for the consideration of Government.

Magnetic survey Operations should not be commenced till the observatory is in thoroughly good working order.

43. Another point of considerable importance in the interests of magnetical science should be alluded to here, although it does not appear advisable that any steps should be taken in connexion with it until the internal machinery of the Observatory is all satisfactorily working; I refer to the establishment of a system of magnetical surveying having for its object the determination of the absolute values of Magnetic Declination, Dip and Intensity at numerous points widely distributed through the country. The probable first outlay for Instruments and tents for this work would be about Rupees 1,900, and a monthly expenditure (exclusive of observer's salary) of Rupees 700 (for some months after the closing of the monsoon) would be involved in travelling and removing the instruments from place to place. Possibly when the new internal arrangements of the Observatory have got into regular operation, the Superintendent may be able to devote a portion of each year to the magnetic survey thus avoiding the necessity for payment of a special observer. While engaged on this duty he may also make a point of inspecting the provincial Meteorological Observatories, visiting them as stations for the survey.

Opinion of Royal Society and British Association as to the importance of magnetic surveys.

Here again it may be stated as showing the estimation of the Royal Society and British Association, of the importance of magnetic surveys, that the Joint Committee (before referred to) recommended that provision should be made

for the execution of such surveys in connexion with each of the proposed Observatories.

Suggestions of the Committee of Enquiry for extending the external relations of the Observatory.

44. It remains now only to notice the suggestions of the Committee of Enquiry that bear upon the external relations of this establishment regarded as a central Government Observatory; these are:—

1*st.*—That all meteorological or magnetical observations made by Public Authority throughout the Presidency should be superintended and rendered available for practical or scientific purposes through the agency of the Observatory.

2*nd.*—That, if telegraphic communication were established with the ports on the Kutch and Koromandel coast, the Observatory might be made of use in giving timely warning to the shipping of cyclones and heavy weather.

3*rd.*—That instruments should be issued to and verified for amateur observers, whose Observatories should be inspected by the Superintendent and their observations be studied, compared and discussed by him.

4*th.*—That thermometers and other meteorological instruments should be verified, at a small charge by the Observatory for all applicants.

Internal operations being of primary importance, claim exclusive attention until they are in a satisfactory state.

45. While fully recognizing the importance of all these undertakings, I respectfully submit, with all due deference, that the right course is to see first that the internal condition and working of the Observatory are satisfactory and such as to enable it to assist and guide, to useful purpose, minor Meteorological and Magnetical Observatories; and as the prosecution of enquiries connected with these projects and the consideration of them in detail with a

view to reduce them to practical working form will necessarily occupy much time, and moreover as they are not essential to the completeness of an institution of this character, I have not deemed it advisable to delay this report on their account, although they should be kept carefully in view, and be rendered effective as soon as the more pressing claims of the Observatory will allow. The testing of Thermometers, being of primary importance to private observers, and the first step towards the establishment of a concerted system of observation, may however be undertaken at once and the necessary apparatus is therefore included in the appended statement of expenses.

Suggestion of Committee to be kept carefully in view for future action.

Testing of Thermometers may be undertaken at once.

46. With regard to the recommendation which is of most practical consequence, that for organizing a system of storm-signals for maritime purposes, it must be remarked that to secure for the warning signals the confidence of those for whose benefit they are designed, a degree of certainty must be attained in the prediction of storms, that requires a better knowledge of their laws in this region than is yet available; and that the procuring and study of comparable observations of storms must precede the attempt to give warning of them.

Storm-signals imply a previous *knowledge of the laws of storms.*

47. Before concluding it may be useful to state that, from the records preserved in the office of the Executive Engineer at the Presidency, it appears that the present Observatory buildings, the principal part of which were erected nearly forty years ago, cost upwards of Rupees 60,000:— allowing for modifications in the plan and construction and for the greatly increased prices of labour and materials, the expense of erection of a new Observatory, in the Island of Bombay, could not therefore be expected to fall much under a lac of Rupees.

Expense of erecting a new Observatory inferred from the actual cost of the present buildings.

48. It may be well in conclusion to summarize shortly the objects that are intended to be attained under the improved conditions of the Observatory as to instrumental equipment and working force.

Objects to be aimed at for the future.

Magnetical.

First then in Magnetism:—Besides a perpetual record of the ever-varying forces which act in each of three rectangular directions; determinations, with the best instruments, will be regularly made of the absolute values of Magnetic Declination and Dip, and of the Intensity of the Horizontal force. These data will suffice to determine:—

1*st.*—Avery accurate mean value of the absolute Intensity and direction of the resultant magnetic force of the earth at Bombay for the period over which the observations extend.

2*nd.*—The laws which govern the changes which this force undergoes, both in direction and Intensity, in periods of one solar day, one year and ten years, and the variations of the diurnal laws at the different seasons of the year.

3*rd.*—The laws which regulate the minute changes that have reference to the moon's hour angle.

4*th.*—The amount of the progressive changes which take place from year to year in the Intensity and Direction of the earth's force.

5*th.*—The laws which are followed in the occurrence of magnetic disturbing forces, of comparatively large amount, with respect to periods of one solar day, one year, and ten years, and for each of the three magnetic elements, Declination, Horizontal Force, and Vertical Force.

These problems have all received solution for several points on the surface of the earth by means of occasional and hourly observations only; but the introduction of continuous photographic tracings has brought to light several remarkable characteristics

of disturbing forces which require verification from more extended application of the methods of treatment; and the comparison of simultaneous individual disturbances in complete detail, for distant points on the surface of the globe is a most promising field for magnetical enquiry as yet almost untouched. It is also reasonably to be presumed that the study of the curves in this manner along with those of other Observatories will suggest new methods of investigation suited to the further elucidation of general facts relating to individual Magnetic storms as distinguished from those, already to a large extent known, which have reference to the aggregate of magnetic disturbing forces occurring in a year or a course of years.

6*th*.—From the accumulated observations of the last twenty years the whole of the results enumerated above, from 1st to 5th will be deduced as closely as the materials will permit; in some respects it is expected that these will be quite satisfactory; while in others, as in absolute measures and secular change of the earth's magnetic force all that is hoped for, is to get a fair degree of approximation to the truth which may be rendered more accurate by comparison with the results derived hereafter from observations with the improved instruments.

7*th*.—In due course the magnetic survey will afford the necessary data for a graphical representation of the distribution of magnetic force over this part of the globe, the permanent interest attaching to which will have reference chiefly to the changes and movements, in long periods, of the magnetism of the earth regarded as a whole; while an immediate result will be the confirmation or otherwise of a remarkable generalization drawn from the observations of the M. M. Schlagintweit, viz: that in passing over the Indian Continent, the Isodynamic lines deviate in a constant direction from their normal course.

In Meteorology—all the usual phenomena of Barometric pres-

Meteorological.

sure, temperature of the air and soil, humidity of the air, rain, direction and force of the wind, ozone &c., will be accurately observed and the results tabulated and co-ordinated for the more easy conception of their significance. Besides, a continuous record will be maintained photographically of the electrical state of the air, from which may be inferred the laws upon which its variations depend, and the relations which may exist between this and other meteorological phenomena. Observations regularly made at out-stations will be reduced and put into the forms best adapted for general usefulness; and it is hoped that the study of these in connexion with each other may lead to some knowledge of the progress of storms in this part of the country, that, after varification by observations at stations properly situated, may form a practical basis for the ultimate introduction of a system of storm signals along the coast.

Practical.

In the service of public interest, observations of stars or other bodies for the determination of time will be maintained as hitherto both for Observatory purposes and for the dropping of the Time-Ball in the Fort by means of a telegraph connecting it with the Observatory clock,* and for the rating of ships' chronometers, belonging both to Government and to the merchant service.

Tidal.

By tidal observations under the improved conditions as to the situation and form of the apparatus, it is expected that the constants in the mathematical formulæ for predicting the tides will be ascertained with the greatest possible accuracy, and also that means of estimating the value of the past observations will be furnished at the same time.

CHAS. CHAMBERS,
Superintendent.

GOVERNMENT OBSERVATORY,
COLABA, 27*th March* 1866.

* The expense of conducting the Time-Ball operations will be borne by the Harbour and Pilotage Board.

Note on the rates of the Sidereal Clock shown in the table forming paragraph 19.

It has been found from observations made by Mr. Hurry Chintamon between the 27th June and 16th July 1866, that the temperature compensation of the Sidereal Clock is very sensibly imperfect. Ten equations were obtained, from as many independent determinations of the error of the clock, of the form $a = A + n R + M \Delta T. t. x$ where

a = the observed error in seconds.
A = the error on June 27th.
R = the daily rate for a constant temperature 82°·0.
n = the number of days from June 27th.
t = the excess of the mean temperature, during a fraction of a day (Δ T), above 82°·0.
M Δ T. t = the sum of the products Δ T. t taken between the limits T = o and T = n.
x = the increase of daily rate when the mean temperature is increased one degree.

From these equations the following values are obtained, by the method of Least Squares: $a = -22{\cdot}78$ R $= -5{\cdot}247$ $x = -{\cdot}155$; and the relation between the calculated and observed errors exhibited in the subjoined numbers, reflects credit on the Observer, while indicating, at the same time, a very satisfactory action of the clock.

Dates.	June 27th	28th	July 2nd	3rd	4th	7th	9th	10th	14th	16th
Observed error.	-22·80	-28·27	-49·72	-55·25	-60·68	-76·27	-86·84	-92·03	-112·10	-122·61
Calculated error.	-22·78	-28·24	-49·81	-55·23	-60·60	-76·26	-86·82	-92·10	-112·11	-122·63
Observed *minus* calculated	- ·02	- ·03	+ 0·9	- ·02	- ·08	- ·01	- ·02	+ ·07	+ ·01	+ ·02

It is evident from these results that if the effects of temperature could have been eliminated from the clock rates shown in January last, these would have presented a much more accordant appearance.

Statement of the probable expense of effecting the proposed alterations for extending, and increasing the efficiency of, the internal operations of the Government Observatory, Bombay.

No.	Description.	Estimated cost.			Total.
	I.—For the purchase of New Instruments, &c.				
1	A set of self-recording Magnetometers for registering by photography changes of Declination, Horizontal Force and Vertical Force, complete	3,460	0	0	
2	Thomson's Electrometer, arranged for photographic self-registration	570	0	0	
3	Apparatus for measuring and tabulating the curves given by the aLovenamed instruments...	300	0	0	
4	Photographic Apparatus, Porcelain dishes, and boxes for paper and photograms	441	0	0	
5	Moffat's Ozonometer, in box with clock-work and rotating cylinder	40	0	0	
6	Beam Compasses, with steel points and tangent screw adjustment, to measure 4 feet (for verification of distances in Deflection experiments).....	60	0	0	
7	Rotating frame with large glass jar and Kew Standard Thermometer for testing thermometers	88	0	0	
8	Charges for verification of the above-named instruments at the Kew Observatory	450	0	0	
	Carried forward.....	5,409	0	0	

No.	Description.	Estimated cost.			Total.		
	Brought forward.....	5,409	0	0			
9	Charges for packing, insurance, freight, &c.	450	0	0			
10	Standard Books of reference, and Treatises on the physical sciences, &c.....	120	0	0			
11	Repair of Transit Instrument ...	150	0	0			
					6,129	0	0
	II.—For alterations and additions required to the Observatory premises to fit them for the use of photographic self-registering instruments and for the accommodation of other new instruments.						
12	Excavating cellar in present Magnetical Observatory, masonry, plastering and flooring, teak partitions and roof with windows, 4 solid stone and 2 wooden pillars, and bench with cupboard (magnetographs to be mounted on basement floor)	6,841	0	0			
13	Fixing a large stone or slate slab in upper room of Electrometer Tower, shutters and dark boxes, bench with cupboard, and copper vessel, (Electrograph to be mounted on the slab).....	159	0	0			
14	Plank partitioning and shutters to convert a portion of room adjoining Astronomical Observatory into a dark room for photographic operations; cistern 2 sinks, cesspool, and gutter...	546	0	0			
	Carried forward.....	7,546	0	0	6,129	0	0

No.	Description.	Estimated cost.	Total.
	Brought forward.....	7,546 0 0	6,129 0 0
15	Fixing of 4 teak beams in walls of second storey of Electrometer Tower, for supporting wooden pillars, isolated from the floor, upon which the instruments for absolute Magnetical Observations are to be placed	537 0 0	
16	Making two windows in small Magnetical Observatory.....	48 0 0	
17	Constructing a removeable protecting cover over the Transit Instrument	65 0 0	
18	Gas-piping and fittings, laying and fixing according to estimate of Bombay Gas Company	711 0 0	
19	Probable expenses of erecting and adjusting magnetographs and electrograph at Colaba, of removing Osler's rain and wind guage to Electrometer tower, and of making deflection bars for finding the scale-coefficients of the present Magnetometers	140 0 0	
			9,047 0 0
	Total, Rupees fifteen thousand one hundred and seventy-six...		15,176 0 0

NOTE.—The estimates for the works included under items 12 to 17 were furnished by the Executive Engineer at the Presidency.

Statement of the estimated average monthly expenditure involved in the proposed alterations.

No.	Description of charges.	Amount.	Total.
	I.—For maintaining the Magnetographs and Electrograph in constant operation and for lighting the Astronomical Observatory.		
1	For photographic chemicals, waxed paper and distilled water ...	30 0 0	
2	For Gas, four lights perpetually burning, others only during the performance of work ..... 60 Less nine-tenths of present consumption of oil and cotton wool for lighting which will become dispensable 22	38 0 0	
3	For increase of pay to 4 Hamals at Rs. 2 each	8 0 0	
4	*II.—For contingent charges on the repair, alteration and adjustment of instruments and for making small additions essential to the successful working of the Observatory, including the purchase of books for the library.*.....	50 0 0	
	Carried forward.....	126 0 0	12 60 0

No.	Description of charges.	Amount.	Total.
	Brought forward.....	126 0 0	126 0 0
	III.—For a temporary special computing establishment.		
5	For 6 Computers at an average salary of Rs. 40 each, to be employed upon a new, and for the most part entire, reduction of the old observations, Magnetical, Meteorological and Tidal.	240 0 0	
			366 0 0
	Total, Rupees three hundred and sixty-six.....		366 0 0

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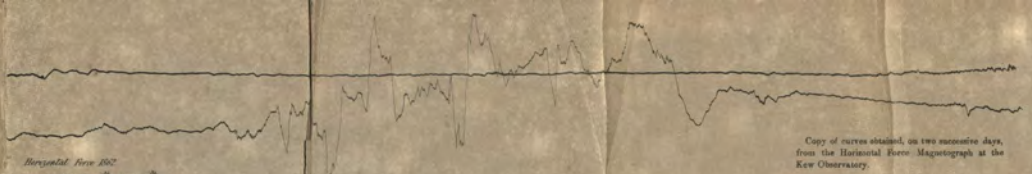


Copy of curves obtained, on two successive days, from the Horizontal Force Magnetograph at the Kew Observatory.

The vibrations drawn thus (increasing from left to right), the commencement and conclusion of each day being expressed in days, hours and minutes of Kew Astronomical Time, and the ordinates represent the varying intensities of the force, an increase of one inch corresponding to a diminution of the force to the extent of about one-hundredth of the whole.

ERRATA.

Page	5	line 9	for	" decennial "	read " discussed."
„	5	„ 10		" decimnal "	" decennial "
"	9	last line		" *an priori* "	" an *a priori* "
"	10	„		" Magnetial "	" Magnetical "
„	44	line 17		" interest "	" interests ".
„	49	last line	omit	" 12 60 0 "	in Total column
„	50	first line	„	" 126 0 0 "	„
„	1	line 2 (heading) after Observatory insert a colon (:)			

Marine Department.
No. 514

Bombay Castle,
26th July 1866.

Letter from the Superintendent, Government Observatory, No. 32 dated 27th March 1866.

Submits a Report on the Instrumental and other requirements of the Government Observatory, for increasing its efficiency and for extending the field of its operations.

Report by the Officiating Superintendent of Marine, No. 184 dated 23rd April 1866.

RESOLUTION—After an elaborate examination of objections raised against the present situation of the Observatory, Mr. Chambers is of opinion that these are not of serious consequence, and that, on the whole, the situation is well adapted to the purposes of the Observatory. With respect to the principal objection, which arises from the vicinity of a battery of 110-Pounder Armstrong Guns, this opinion is derived from the results of observations given in detail in the Report made simultaneously with the firing of the Guns, and thus showing the actual effects produced upon the Magnetometers, Transit Instrument, Collimator, Clocks, Chronometers, &c., then lying in the Observatory. He then suggests certain Instrumental improvements (for assimilating the equipment of instruments to that of the best modern Observatories) and alterations of the Observatory premises, consisting principally of the provision of a set of photographic self-recording Magnetometers, and the alteration of the present Magnetic Observatory to suit it for their reception, and also the temporary employment of a body of six Computers for the reduction of the accumulated observations. The judiciousness of these recommendations can only properly be tested by persons familiar with the working and objects of the most advanced Magnetical and Meteorological Observatories, and His Excellency in Council therefore resolves that the recommendations be referred, along with the considerations by which Mr. Chambers arrives at his conclusion regarding the site of the Observatory, to some competent authority at Home, and in the event of their being approved, that the execution of the improvements recommended and the provision of a special Computing force should be sanctioned.

Copies of the report, and its accompaniments, will be forwarded to the Secretary of State and to the Government of India.

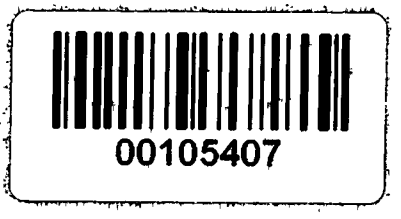
The Secretary of State will be requested to furnish copies to the Royal Society of London and to the British Association for the Advancement of Science, and their aid invoked in support of Mr. Chambers' recommendations for rendering the Observatory more efficient.

Copies will also be furnished to the learned Societies here, in Calcutta and Madras, and to the Press.

J. M. MACDONALD,
Major,
Acting Secretary to Government.

To

C. CHAMBERS, ESQ.,
THE SUPERINTENDENT OF MARINE.
THE BOMBAY HARBOUR AND PILOTAGE BOARD.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